4135/4136

INSTRUCTIONS AND APPLICATIONS

Quarter-inch Condenser Microphones

Microphone Cartridges Type 4135/36 and associated cathode follower.

Precision condenser microphones for laboratory measurement purpose. Each microphone is individually calibrated. Frequency range of calibration: 20 Hz—200 kHz. Dynamic range up to 180 dB.

- Accelerometers
- Acoustic Standing Wave Apparatus
- Artificial Ears
- Artificial Voices
- Audio Frequency Response Tracers
- Audio Frequency Spectrometers
- Audio Frequency Vacuum-Tube Voltmeters
- Automatic A. F. Response and Spectrum Recorders
- Band-Pass Filter Sets
- Beat Frequency Oscillators
- Complex Modulus Apparatus
- Condenser Microphones
- Deviation Bridges
- Distortion Measuring Bridges
- FM-Tape Recorders
- Frequency Analyzers
- Frequency Measuring Bridges
- Hearing Aid Test Apparatus
- Heterodyne Voltmeters
- Level Recorders
- Megohmmeters
- Microphone Accessories
- Microphone Amplifiers
- Microphone Calibration Apparatus
- Mobile Laboratories
- Noise Generators
- Noise Limit Indicators
- Pistonphones
- Polar Diagram Recorders
- Preamplifiers
- Precision Sound Level Meters
- Recording Paper
- Strain Gage Apparatus and Accessories
- Stroboscopes
- Variable Frequency Rejection Filters
- Vibration Pick-ups
- Vibration Pick-up Preamplifiers
- Wide Range Vacuum Tube Voltmeters
- Vibration Programmers
- Vibration Control Signal Selectors
- Vibration Control Generators
- Vibration Meters

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Quarter-inch

Condenser Microphones

Type 4135/4136

June 1969

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1. Introduction

Purpose of the Quarter-inch Microphones.

The B & K Quarter-inch Condenser Microphones are designed for precision sound pressure measurements. Because of their small dimensions, they leave the sound fields undisturbed at audible frequencies and their first resonance frequency is far above the audible range. They have consequently very flat frequency responses and excellent responses to sharp pulses as illustrated in the Appendix. In addition, they allow measurements without distortion of very high sound pressure levels (up to 180 dB) as missile exhaust noise etc. On the other hand they are not suited for low sound level measurements (below 70 dB).

Their most outstanding feature is excellent long-term stability under a great range of environmental conditions and especially their insensitivity to temperature variations. They are therefore well suited for field measurements, though the accuracy of calibration matches laboratory standard requirements.

Principle of the Condenser Microphone.

A condenser microphone consists essentially of a thin metallic diaphragm mounted in close proximity to a rigid back plate. Diaphragm and back plate are electrically insulated from each other and constitute the electrodes of a capacitor. See Fig. 1.1. Housing and insulator form with the diaphragm

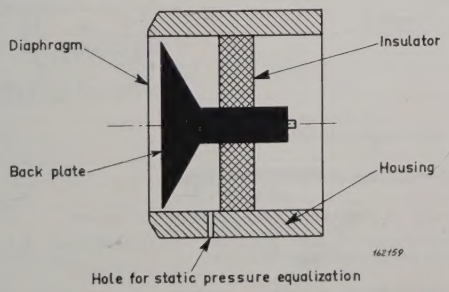
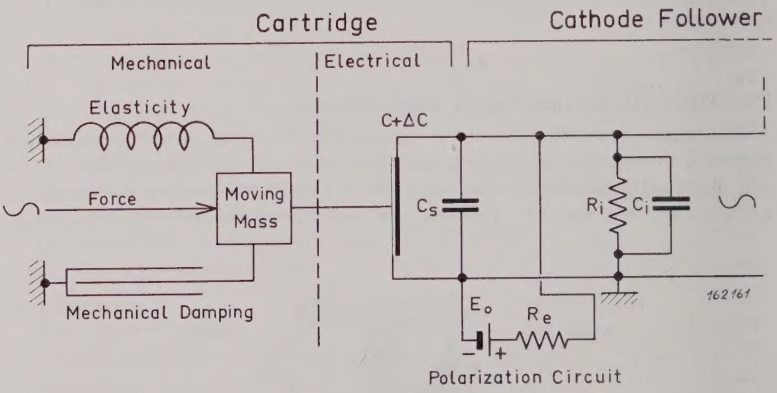


Fig. 1.1. Schematic construction of a condenser microphone cartridge.

a closed chamber, which is only in communication with the outside for slow static ambient pressure variations. When the microphone is exposed to a sound pressure, the diaphragm is submitted to an alternating force proportional to the pressure and the diaphragm area. The consequent movement of the diaphragm varies the capacity, and these variations are transduced into an AC voltage component if a constant charge is present between the electrodes. The charge is obtained by means of a stabilized DC polarization voltage, and it remains constant as long as the charging time constant of the circuit is much longer than the period of the sound pressure variations. It is possible by careful design to maintain the proportionality of the AC output voltage to the sound pressure within a wide frequency range and an extended dynamic range. The widest linear frequency range for the pressure response is obtained if the resonance of the mechanical system (diaphragm) is critically damped. This damping, which is due to the back-and-forth movement of the air contained between diaphragm and back plate, is determined by the shape of the back plate, the mechanical tension of the diaphragm, and the spacing between plate and diaphragm.
The low frequency limit of the linear range is set by the "cut-off" (or time



C = Polarized cartridge capacity

ΔC = Variation of capacity producing the signal

C_s = Stray capacity of connection to cathode follower

R_i,C_i = Input impedance of cathode follower

Fig. 1.2. Simplified diagram of the condenser microphone. (The electrical leakage in the cartridge is neglected).

constant) of the microphone cartridge circuit. Referring to the schematic diagram of Fig. 1.2 the cut-off frequency is:

$$f_o = \frac{1}{2\ \pi\ (C + C_a + C_i)\ \frac{R_i\ R_e}{R_i + R_e}}$$

Since the sensitivity of the microphone is determined by the relative variation of capacity $\Delta\ C/(C + C_a + C_i)$, the total parallel capacity should be made as small as possible. The first amplifier stage is therefore built in the same housing as the microphone. A preamplifier providing a very large input impedance is employed, because small parallel capacity requires high R_i and R_e in order to obtain a satisfactory low limiting frequency.

Definitions.

Free-field and Pressure Response.

The *Free-field Response* of a microphone is the ratio of the r.m.s. output voltage to the r.m.s. sound pressure existing in the free field at the microphone location with the microphone removed from the sound field.

The *Pressure Response* of a microphone is the ratio of the r.m.s. output voltage to the r.m.s. sound pressure, uniformly applied over the diaphragm. The two definitions coincide for a microphone having negligible dimensions with respect to the sound wavelength. In the case of the B & K quarter inch microphones this is practically fulfilled up to about 5300 Hz,*) where the wavelength equals ten times the diameter of the microphone (i.e. 63.5 mm). The difference in response is then less than one decibel.

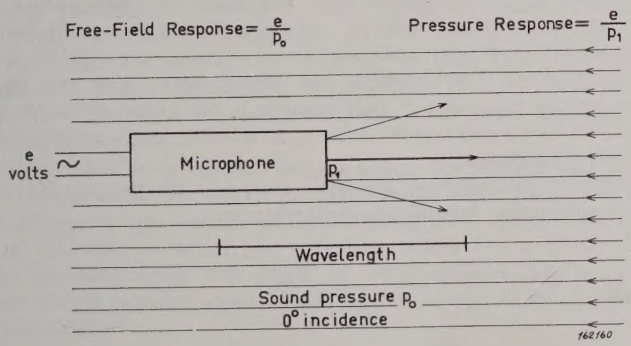


Fig. 1.3. Definitions of Free-field and Pressure response.

*) Hz international
c/s used in United Kingdom and U.S.A.

At higher frequencies the diffraction of the sound waves by the microphone produces an appreciable change in the resulting sound pressure acting on the microphone diaphragm as illustrated in Fig. 1.3. The difference $p_1 - p_0$, called *free-field correction,* depends on the orientation of the microphone with respect to the direction of propagation of the sound and on the external dimensions of the microphone (in particular those of the front and of fitted protective grids or "nose cones").
The free-field behaviour of a microphone is thus described by means of a set of free-field correction curves for various incidences, which should be added to the pressure frequency curve of the microphone in each particular case. See Figs. 2.14—2.16.
For microphones intended for free-field work it is possible to give the diaphragm resonance such a damping that the normal incidence free-field corrections are compensated for up to frequencies well above the resonance frequency, in order to obtain the flattest possible frequency response.

Random Incidence Response (Diffuse Field Response).
The random incidence response of a microphone for a given frequency is the root-mean-square value of the free field sensitivity for all angles of incidence of the sound wave. It corresponds to the diffuse field sensitivity of the microphone, the diffuse field being a sound field in which the sound energy density is uniform and the mean acoustic power per unit area is the same in all directions. The International Electrotechnical Commission (publication no. 123, § 8.2) has given a practical rule for the calculation of the random incidence sensitivity from the free-field sensitivities at definite angles, with coefficients proportional to the relative solid angles.*)
Figs. 2.3 and 3.2 show the random incidence frequency response of the different B & K quarter-inch microphone combinations. These curves should be taken into consideration in the case of measurements in highly reverberant rooms giving rather diffuse field conditions.
When the spectral distribution of the sound varies with the angle of incidence, correct integration is only possible in the range where the microphone is both linear and omnidirectional (practically up to 20 kHz with the quarter-inch microphones).
Omnidirectional microphones are also necessary in the case of rapidly moving sound sources (aeroplanes, motorcars, etc.).

*) S_0, S_{30}, S_{60}, - - - - S_{180} being the sensitivity of the microphone at angles of incidence of 0°, 30°, 60°, - - - - 180°, the random incidence (diffuse field) response S is given by the formula:

$$S^2 = 0.018\ (S_0^2 + S_{180}^2) + 0.129\ (S_{30}^2 + S_{150}^2) + 0.224\ (S_{60}^2 + S_{120}^2) + 0.258\ S_{90}^2$$

2. Description

General Description of the Equipment.

A complete microphone consists of a microphone cartridge and a preamplifier or cathode follower for impedance conversion, allowing long cables and relatively low input impedance amplifiers to be used between the microphone and the measuring instrument. The microphone cartridge is screwed onto the housing of the cathode follower by means of an adaptor making a small, rugged unit. Fig. 2.1.

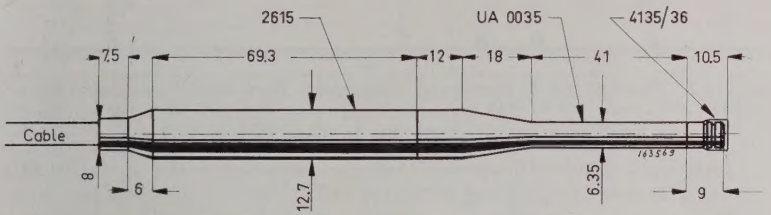


Fig. 2.1. Quarter-inch microphone with outer dimensions in mm (1 mm = 0.03937 inch).

The microphone may be directly connected to the different B & K measuring instruments which are provided with a "Condenser Microphone" input socket fitting the microphone connecting plug. Stabilized voltages for the pre-amplifier and polarization voltage for the cartridge are available on this seven-pin socket. The microphones may also be used with other equipment when operated from a Microphone Power Supply Type 2801 which provides the necessary voltages in the same conditions as the B & K measuring instruments (see Accessories).

For free-field and room-acoustic measurements, the microphones should be placed remote from the measuring instruments, since these would often disturb the sound field because of their non-negligible dimensions. Different types of microphone stands and extension cables are available for this purpose, see Accessories. The length of cable, however, has a significant influence on the response above 40 kHz as will be seen in the description of the preamplifier.

Quarter-inch Condenser Microphone Cartridges.

Two different types are available:

1. The Microphone Cartridge Type 4135, with a sensitivity of 0.2 mV/μbar,

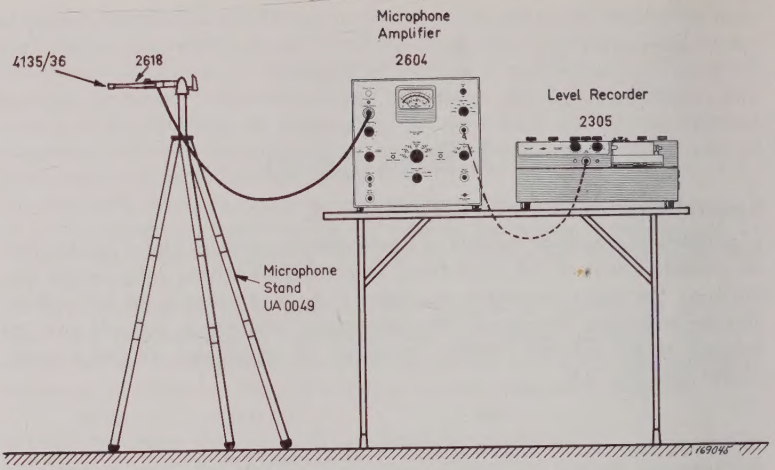


Fig. 2.2. Typical B & K measuring equipment. Both amplifier and level recorder are linear up to 200 kHz. Analyzers are also available for automatic plotting of spectrograms in the range 22 Hz—45 kHz.

featuring a free-field frequency characteristic which is flat up to 100 kHz and a dynamic range going up to 174 dB.

2. The Microphone Cartridge Type 4136, with a sensitivity of 0.1 mV/μbar, having a pressure frequency characteristic which is flat up to 70 kHz and a dynamic range going up to 180 dB.

The difference in characteristics is illustrated in Fig. 2.3.

The two cartridges have the same mechanical construction (Fig. 2.4) differing only in the diaphragm which is 2 μ (80 μ") thick in the case of the 4135 and 6 μ (240 μ") thick for the 4136. The latter thickness and the shape of the back plate have been determined in order to achieve critical damping of the diaphragm resonance of the 4136. In this way the widest possible flat frequency range of the pressure response is obtained. To the thinner diaphragm of the 4135 corresponds a higher damping factor and thus a fall of the pressure response. The thickness of 2 μ has been chosen in order to obtain a fall in pressure response which compensates exactly the free-field pressure increase at normal incidence for the cartridge without protecting grid. The pressure increase with grid is appreciably higher and, above 50 kHz, it is rather dependent on how tight the grid is screwed onto the cartridge. Measurements involving ultrasonic frequencies should therefore be carried out with the grid removed. However, the random incidence pressure increase with grid appears to be practically equal up to 40 kHz to the normal incidence pressure increase without grid, and it is therefore advantageous to keep the grid on in the particular case of diffuse field measurements with the 4135.

Towards the low frequencies the response of the cartridges is only affected

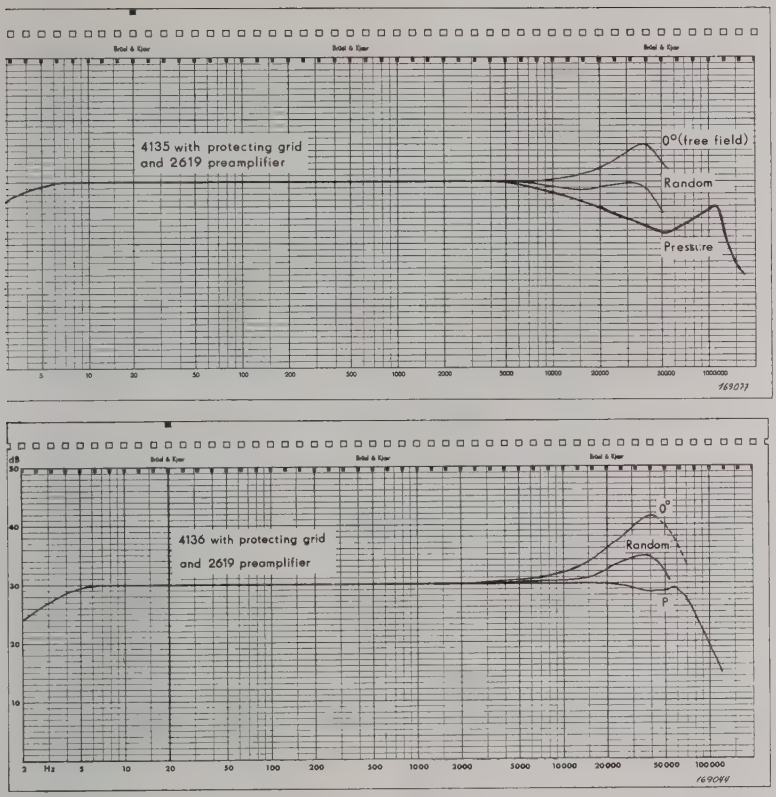


Fig. 2.3. Most significant frequency characteristics of the quarter-inch microphones.

by the influence of the **pressure equalizing arrangement.** This arrangement consists of a capillary leakage hole through which the equalization of the static air pressure on both sides of the diaphragm is obtained at a suitable rate. The influence of ambient pressure (or altitude) variations on the microphone sensitivity has been practically eliminated by proper design of the pressure equalization hole. The time constant of the pressure equalization of the quarter-inch cartridges corresponds to a — 3 dB cut-off frequency between 0.5 and 5 Hz.

The mechanical construction of the cartridges is shown in Fig. 2.4. The choice of the materials and the design of the suspensions of the different parts are made principally with a view to obtaining the best possible long-term **stability** and temperature independency of the sensitivity.

In particular, the diaphragm is not clamped but electro-deposited onto the tensioning ring, forming one mechanical piece. The tension of the diaphragm is thereby unaffected by temperature variations. The cartridges are also subjected to a complete artificial aging process during manufacture consisting of controlled temperature variations over at least two weeks. The basic parts are made of high nickel alloy (K-Monel). The insulator used is silicone treated quartz and for guaranteeing a noise-free connection to the preamplifier, gold-plated contacts are used.
The diaphragm is mounted at a distance of 18 μ from the back plate. The

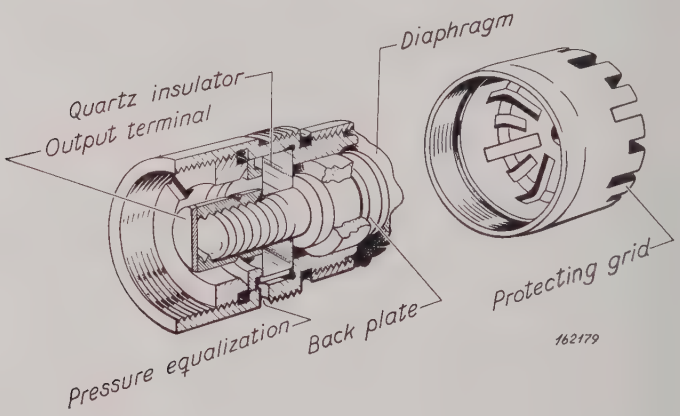


Fig. 2.4. Exploded view of a 1/4" microphone cartridge.

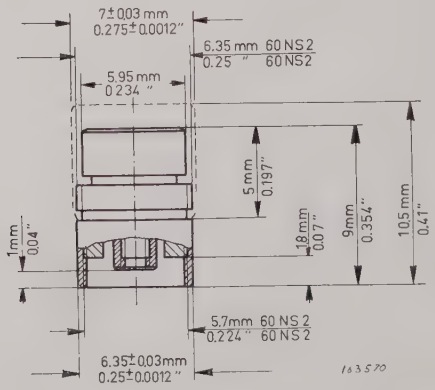


Fig. 2.5. Dimensions of the 1/4" microphone cartridges Type 4135—4136.

polarized cartridge capacity, which is of the order of 6 pF, is measured individually for each cartridge (see the calibration chart). The insulation is verified as higher than 10^5 MΩ.

Cleansing of the Microphone Diaphragm.

CAUTION. On no account should the diaphragm come into contact with fingers or other objects. The protecting grid should only be removed when absolutely necessary. Should the diaphragm become contaminated by liquids or dust it may be dried off with cottonwool or a very soft paint-brush, using great care, and if necessary a proper solvent. The diaphragm will not normally corrode, but any appreciable added mass will change the frequency response.

Preamplifiers.

The 4135 and 4136 microphones possess a very small capacitance, and as mentioned in Section 1, they must be used with a preamplifier possessing a very high input impedance, and small parallel capacitance. This is in order to preserve the low frequency response and overall signal level.

The B & K range of microphone preampifiers are specially designed to meet the requirements of the microphone cartridges. The microphones screw directly onto the first stages of the preamplifiers (or by means of screw adaptors), thus eliminating cable shunt capacitance. The input stages of the preamplifiers are field-effect transistors (FET) or cathode followers, ensuring a very high input impedance. They are powered by the measuring or indicating instruments in the B & K range to which they plug directly.

Preamplifier Type 2618.

The 2618 is especially recommended to be used with the 1/4 inch and 1/8 inch microphones.

The preamplifier Type 2618 consists of a field effect transistor input stage contained in the plated brass housing to which a 1/4" microphone can be screwed direct. By means of an adaptor UA 0160 the 1/8" microphone cartridge can be used. At the other end of the cable, built as part of the plug, are the remaining stages of the preamplifier. This part contains a switch for the gain setting.

Gains of + 20, 0, — 20 dB are possible by turning this switch. The plug is a 7-pin B & K plug designed to fit B & K analysing equipment in the socket marked CONDENSER MICROPHONE, when all the necessary power supplies will be automatically connected.

The low frequency cut-off is determined mainly by the pressure equalization time constant of the microphone whilst the high frequency response depends on the capacitive current which can be delivered by the amplifier output. (See 2618 Instruction Manual).

Due to the guard ring input of the preamplifier, the input capacitance increases with frequency (because of a slight phase shift) and thus causes a loss of sensitivity at high frequencies. The change in capacitance is shown in Fig. 2.6.

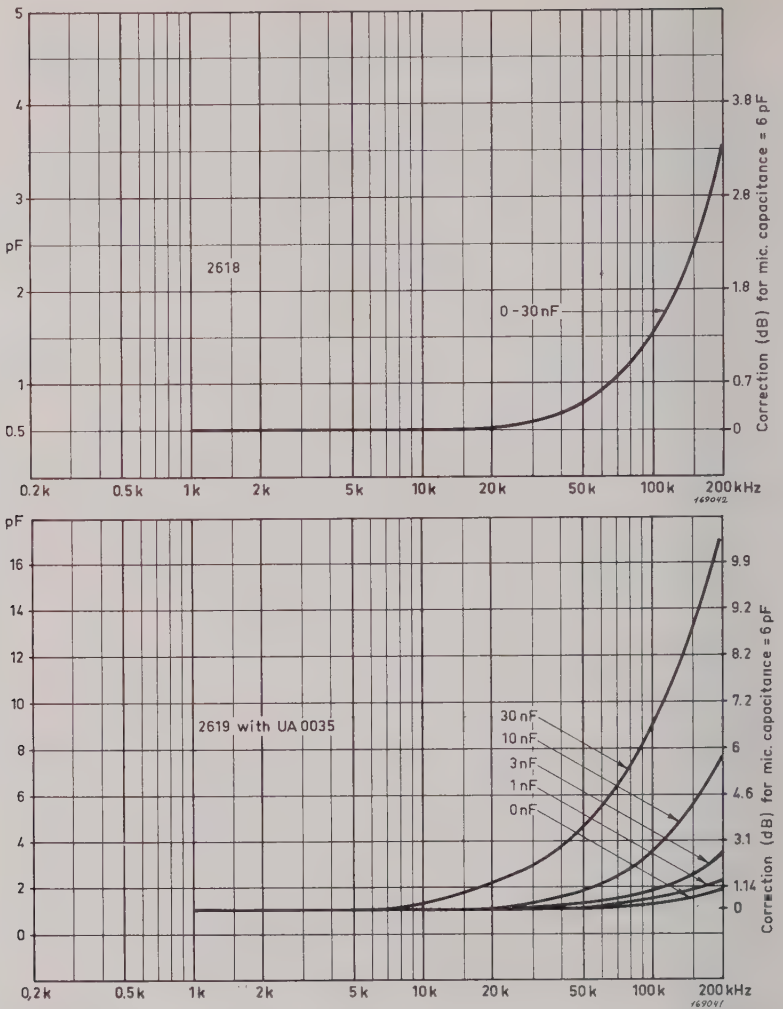


Fig. 2.6. Change in input capacitance of preamplifiers 2618 and 2619 aue to capacitive load. Sensitivity change shown is for a microphone capacitance of 6 pF.

The accuracy of the gain in the linear region is ± 0.2 dB, so that the microphone and preamplifier together form a very accurate measuring transducer for sonic and ultrasonic applications. For a fuller description please refer to the Instruction Manual for this instrument.

Preamplifier Type 2619.

The Type 2619 is also a high input impedance preamplifier with a FET input stage. It takes the 1/2 inch microphones directly, but by means of adaptors, it can be used with the full range of B & K condenser microphones.

The 1/4 inch microphone is used together with adaptor UA 0035, and screws directly onto the input stages of the preamplifier. The remaining stages are at the other end of the cable, contained in a plug which fits the CONDENSER MICROPHONE socket of B & K analyzing instruments. The preamplifier derives its power from the instrument into which it is plugged.

The frequency response of the 2619 is flat from 2 Hz to 200 kHz, so easily covering the frequency ranges of the 4135 and 4136. The gain is very close to unity (0 dB) in the linear region, with a dynamic range of 115 dB (5 dB above noise to 4 % distortion).

For full details of the 2619 preamplifier, please see the Instruction Manual for this instrument.

Preamplifier Type 2615.

The 2615 is a cathode follower preamplifier, using a vacuum tube input circuit. There is no Instruction Manual available for this instrument, but it is described in the Appendix on page 37 of this manual.

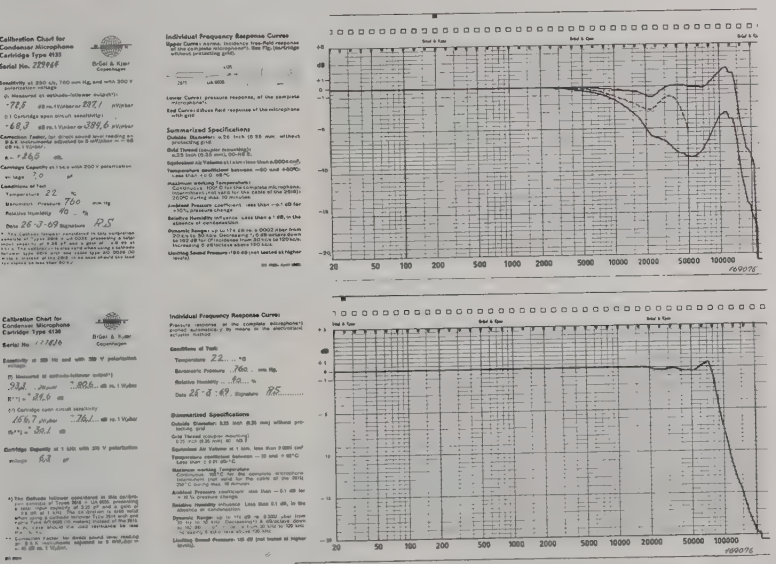


Fig. 2.7. Calibration charts supplied with each microphone cartridge. The pressure response is plotted automatically with an accuracy of ± 0.2 dB up to 10 kHz and ± 0.5 dB up to 200 kHz.

Characteristics of the Quarter-inch Microphones.

1. Sensitivity.

The nominal sensitivity of the quarter-inch microphone is 0.2 mV/μbar (— 74 dB re 1 V/μbar) when equipped with a 4135 cartridge and 0.1 mV/μbar (— 80 dB re 1 V/μbar) with a 4136 cartridge. However, the cartridges are individually calibrated and the actual sensitivities may lie between $\pm$ 3 dB of the nominal values.

On the calibration chart (Fig. 2.6) which is delivered with each cartridge is also given the cartridge open circuit sensitivity (about 4 dB higher than the sensitivity of the complete microphone depending on the cartridge capacity) and a factor K equal to the difference between the microphone sensitivity to which the sound level graduation of the B & K instruments is referred and the particular microphone sensitivity.

2. Frequency Response.

Each cartridge is provided with an individually plotted frequency response chart (Fig. 2.7). Three curves are given for the 4135:

(a) The pressure response (with a cathode follower 2619 + UA 0035).

(b) The normal incidence free-field response of the complete microphone without protecting grid.

(c) The random incidence diffuse field response of the microphone with protecting grid (only defined up to 50 kHz).

Only the curve (a) is actually measured on each cartridge. The other curves

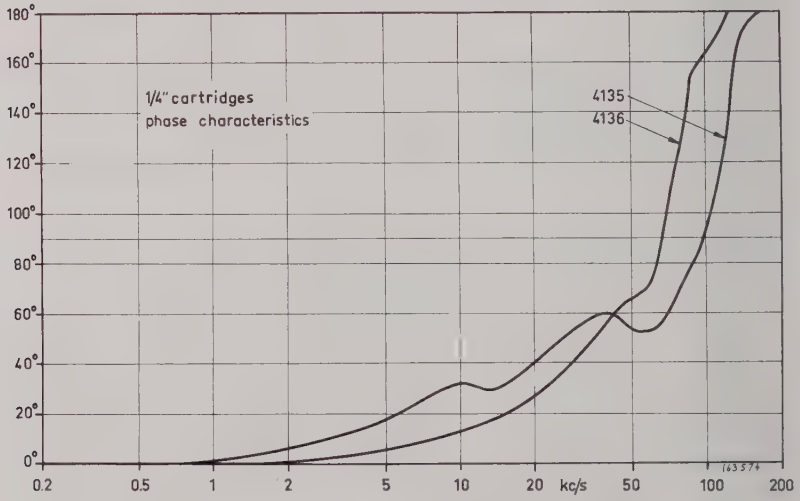


Fig. 2.8. Typical pressure-response phase-angle characteristics of the quarter-inch microphone cartridges.

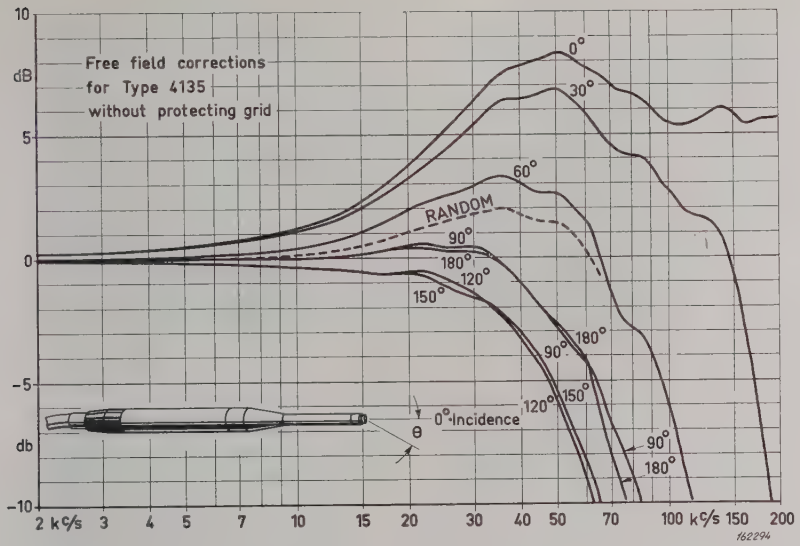


Fig. 2.9. Free field corrections for the quarter-inch microphone equipped with a cartridge Type 4135 without grid.

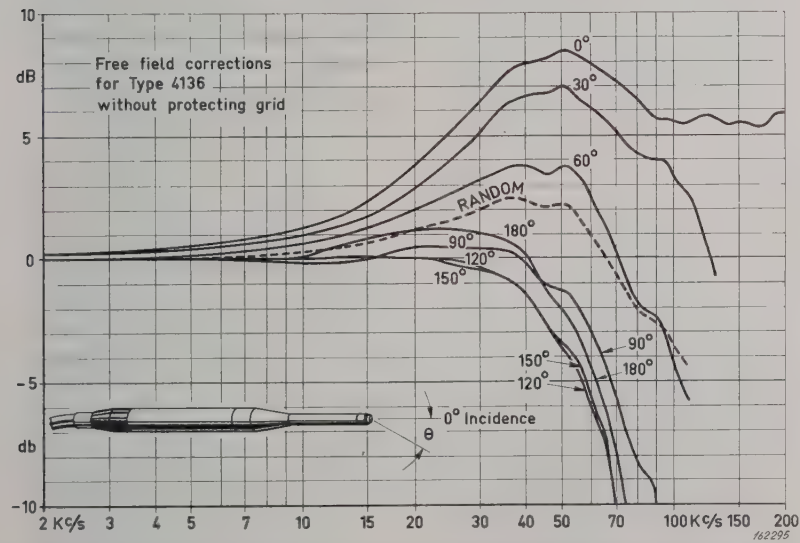


Fig. 2.10. Free field corrections for the quarter-inch microphone equipped with a cartridge Type 4136 without grid.

differ from (a) by an amount which is equal to the respective correction and has been determined once for all. For further details, see item 4: "Free-field corrections".
With the cartridge Type 4136, only curve (a) is given.
If the open-circuit frequency characteristics of the cartridges have to be considered, they can be deduced from the given curves by applying a correction.

3. Phase Characteristics and Pulse Responses.

Typical pressure response phase angle characteristics of the quarter-inch microphones are shown in Fig. 2.8. The fundamental resonance of the diaphragm in vacuum occurs at about 50 kHz, but when air at normal pressure is present between back plate and diaphragm the center of the diaphragm is virtually blocked and the first resonance appears at a higher mode around 70 kHz.
Fig. A.6 in Appendix shows some examples of pulse responses.
N.B. With positive polarizing voltage as in the normal B & K microphones, the output signal is negative-going for positive pressure on the diaphragm. There are other systems where this is not necessarily the case, as for example the AC carrier system.

4. Free-field corrections.

The free-field correction curves for incidences from 0° to 180° are given

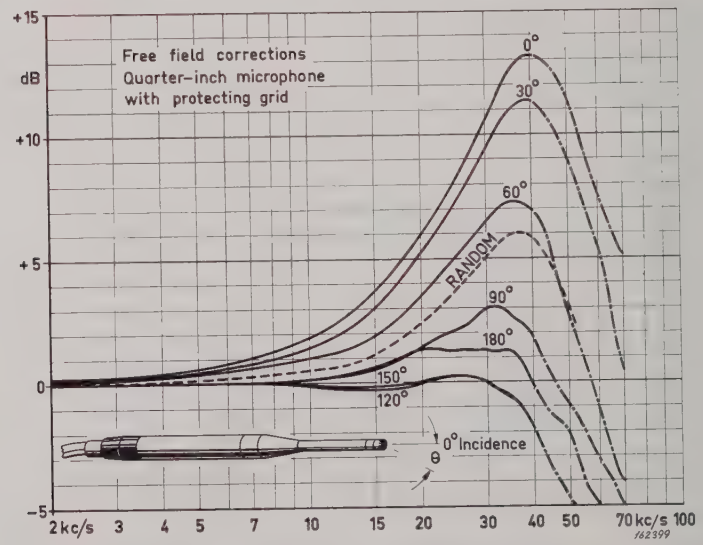


Fig. 2.11. Free field corrections for the quarter-inch microphone with protecting grid.

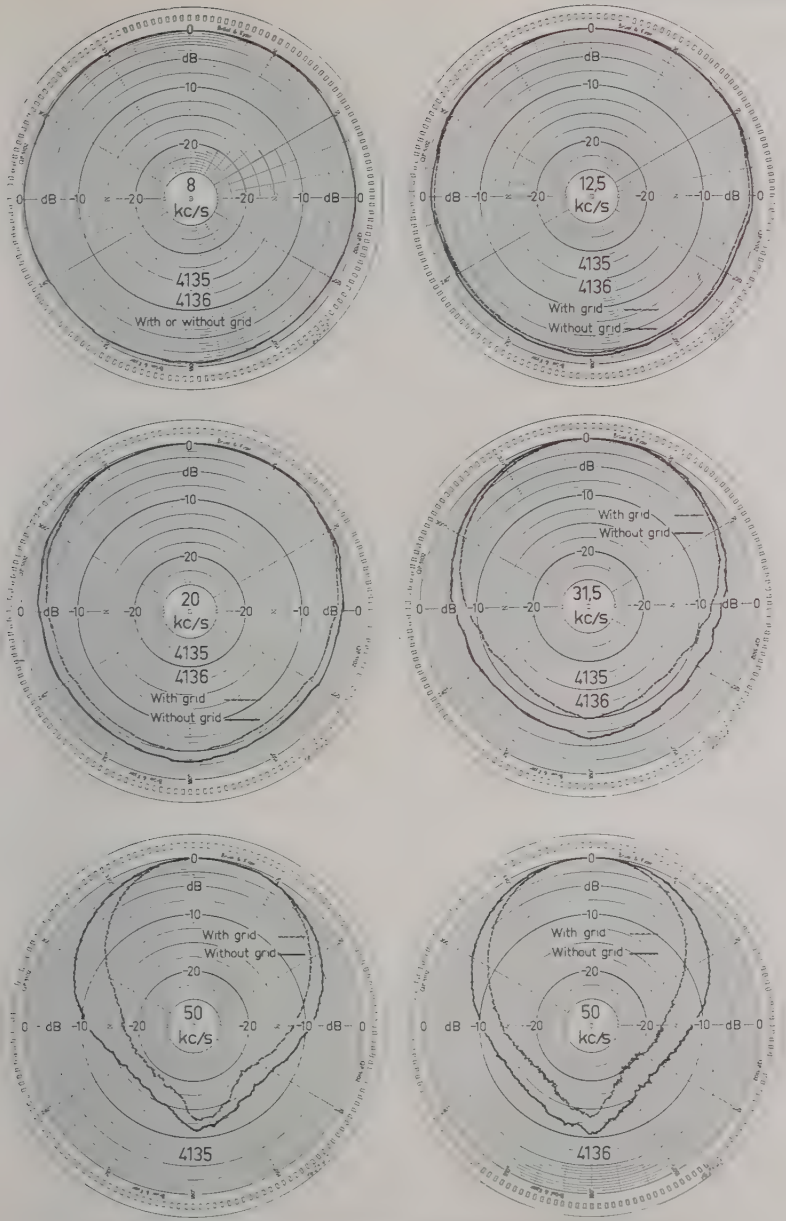
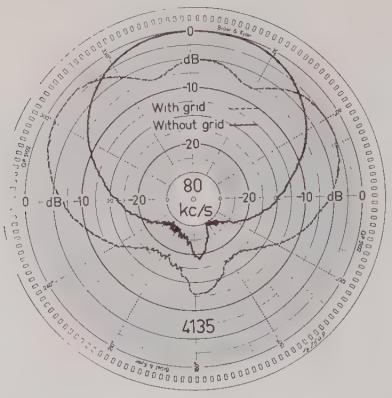
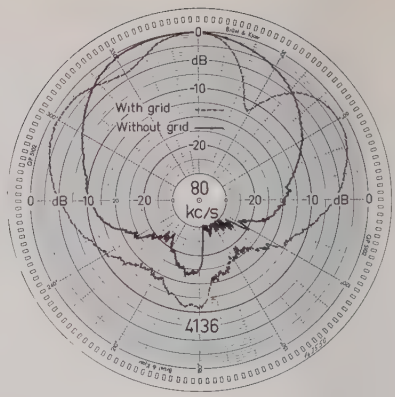
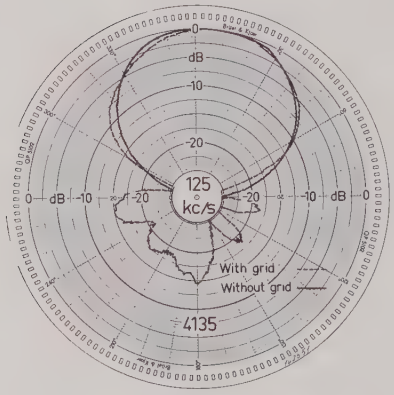
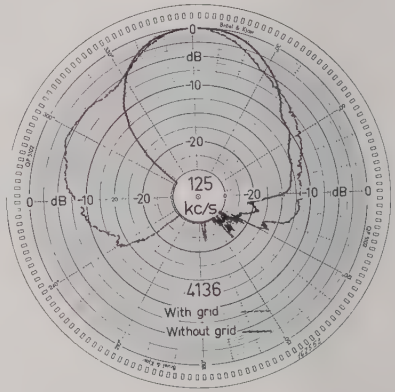


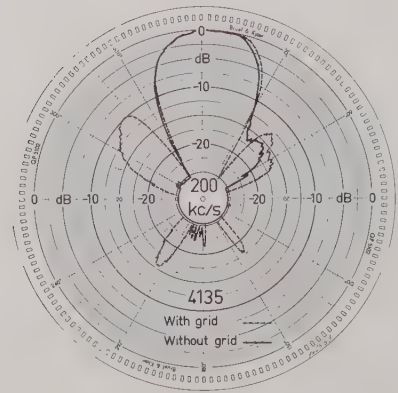
Fig. 2.12. Directional patterns of the quarter-inch microphones.

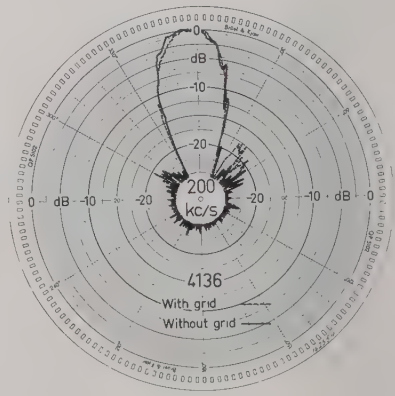

dB
-10
With grid
Without grid
-20
80
c/s
kc/s
4135


dB
-10
With grid
Without grid
-20
80
c/s
kc/s
4136


dB
-10
-20
125
c/s
kc/s
With grid
Without grid
4135


dB
-10
-20
125
c/s
kc/s
4136
With grid
Without grid


dB
-10
-20
200
c/s
kc/s
4135
With grid
Without grid


dB
-10
-20
200
c/s
kc/s
4136
With grid
Without grid

in Figs. 2.9—2.11. They are practically identical for both cartridges up to 40 kHz but they differ slightly at higher frequencies. Above 50 kHz, they are only well defined for the microphone without protecting grid, because the wavelength being only a few millimeters interferes with the dimensions and position of the grid slots. (The wavelength in air is 1.6 mm at 200 kHz).

To obtain the frequency response of a cartridge at a particular incidence the free-field corrections are to be added to the individual pressure response, as is done for 0° incidence on the calibration chart of each 4135 cartridge (Fig. 2.7). The random incidence (diffuse field) corrections of the microphone with grid, which are roughly equal to the 0° incidence corrections without grid, are also included in the random incidence response represented on the calibration charts.

5. **Directional Characteristics.**

See Fig. 2.12. Since both types of cartridges have the same mechanical dimensions, their directional properties are identical up to around 40 kHz. However, small changes in the pattern above 40 kHz may be found from unit to unit due to very slight differences in the mechanical configuration, and as mentioned above, the influence of the protecting grid above 50 kHz cannot be well defined (the dotted patterns are only shown above 50 kHz in order to illustrate this fact).

From Figs. 2.9—2.12 is seen that the quarter-inch microphones are omnidirectional within ± 1 dB up to 10 kHz and within ± 3 dB up to 20 kHz.

A better omnidirectivity (± 3 dB up to 40 kHz) is achieved when using the Nose Cone UA 0053. See Section 3.

6. **Dynamic Range.**

The lower limit of the dynamic range is set by the thermal noise level of the preamplifier when loaded with the cartridge capacitance. The preamplifier Type 2618 generates about 70 μF of noise in a band 20 Hz – 200 kHz, with 6 pF across the input (cartridge capacitance = 6.4 pF). This sets the lower limit of the dynamic range of the 4135/2618 combination to 65 dB in the wide band, 55 dB when A weighted. The corresponding figures for the 4136/2618 combination are 71 dB and 61 dB respectively. With analysis by 1/3 octave filters, the noise level is usually less than 10 μV, but is a function of frequency, as shown in the instruction manual for the 2618. Note that the equivalent sound levels given above correspond to the thermal noise levels. It is usual to add 5 dB when quoting lower limits to the dynamic range, since a signal-to-noise ratio of 5 dB means an easily discernable signal.

The amplifier noise limits and the 4 % distortion limits for the microphones are shown in Fig. 2.13. The level at which contact between back plate and diaphragm is possible is about 185 dB, and the cartridges should not be exposed to levels higher than this.

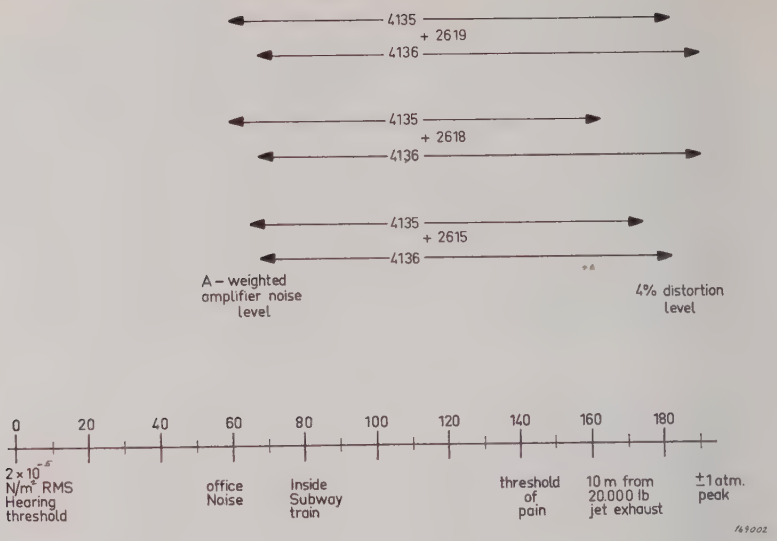


Fig. 2.13.

7. **Equivalent Air Volume.**

At frequencies up to 50 kHz where the motion of the microphone diaphragm is controlled only by stiffness, the acoustical impedance of the microphone is capacitive. In dealing with closed cavity measurements (coupler measurements) in this frequency region it is therefore convenient to express the impedance in terms of an equivalent volume V_a:

$$V_a = \frac{\gamma P}{j \omega Z_a}$$

where γ = ratio of specific heats (1.41) P = ambient pressure and Z_a = acoustical impedance of the microphone. The equivalent volume of the quarter-inch microphones being, however, smaller than 0.0005 cm^3 (½ mm^3) it will be negligible in the great majority of cases.

8. **Influence of the Polarization Voltage.**

The condenser microphone cartridges have been designed to operate with a polarization voltage of 200 volts.

The polarization voltage supplied from the instrument to which the condenser microphone is connected should be adjusted to 200 volts before measurements are taken. Adjustment instructions will be found in the respective manuals.

If the quarter-inch cartridges are operated with other polarization voltages (from 150 to 250 volts) the sensitivity is modified proportionally. The shape

of the frequency response curve remains practically unchanged (within ± 0.2 dB). The cartridges are not tested above 250 volts.

9. **Temperature Characteristics.**

As mentioned in the description, special care has been taken during the development and subsequent manufacture of the microphone cartridges to obtain a characteristic which to a high degree is independent of temperature.

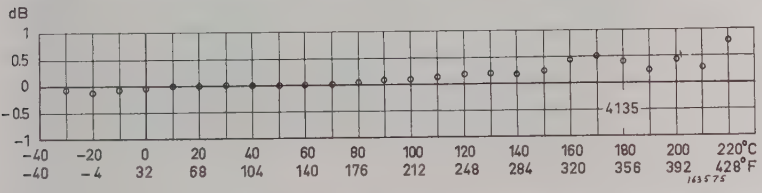


Fig. 2.14. Typical sensitivity versus temperature check on a cartridge Type 4135 at 1000 Hz.

Typical temperature-sensitivity charts are shown in Figs. 2.14 and 2.15 and the variations in frequency responses at different temperatures are seen in Figs. 2.16 and 2.17.

The cartridges and adaptor UA 0035 stand temperatures of up to 150°C (300°F) continuously and up to 250°C in short periods (10 min.). However, the insulation material used in the connecting cables of the preamplifier should not be exposed to higher temperatures than 100°C (212°F).

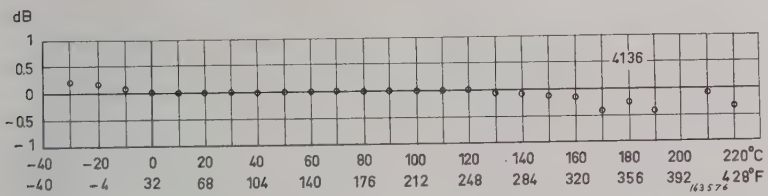


Fig. 2.15. Typical sensitivity versus temperature check on a cartridge Type 4136 at 1000 Hz.

Note: Subjecting the quarter-inch cartridges to temperatures around 200°C for more than 10 minutes will not damage the microphones but will produce a permanent change in characteristics.

For example after one hour at 220°C and return to 25°C, a 4135 cartridge showed a sensitivity which was increased by 3.6 dB in the flat part of the frequency response and 1 dB in the range 20—80 kHz.

10. **Influence of Ambient Pressure.**

The microphone sensitivity will vary less than — 0.1 % for + 10 % variations

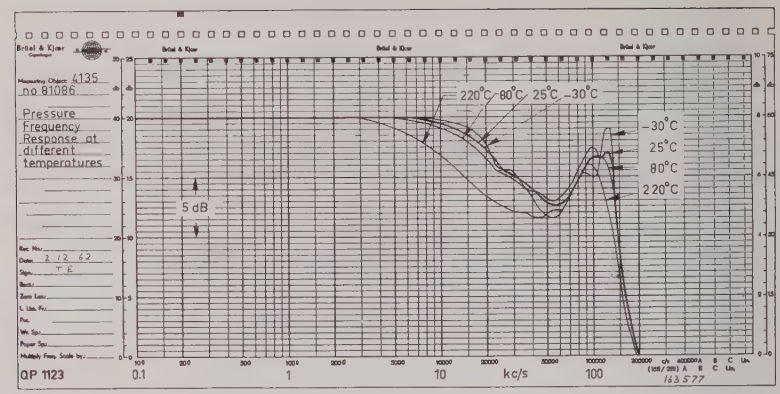


Fig. 2.16. Influence of temperature on the frequency response of the 4135.

in ambient pressure. For important changes in ambient pressure the frequency response of the microphone will be modified, especially towards the higher frequencies, because of the change in mechanical damping. The frequency response at different ambient pressures is given in Fig. 2.19. The influence of varying altitude is very small: a rate of climb of 10 km/sec at ground level affects the sensitivity less than 1 dB.

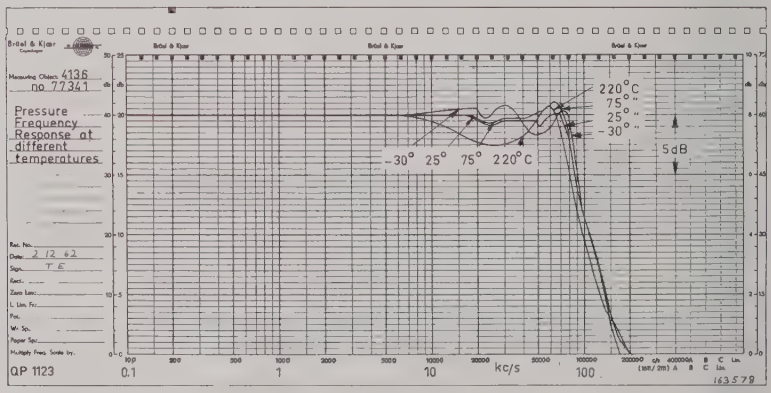


Fig. 2.17. Influence of temperature on the Frequency response of the 4136.

11. Influence of Humidity.

Large variations of ambient temperature may in some cases cause moisture condensation to take place between the diaphragm and the electrode of the

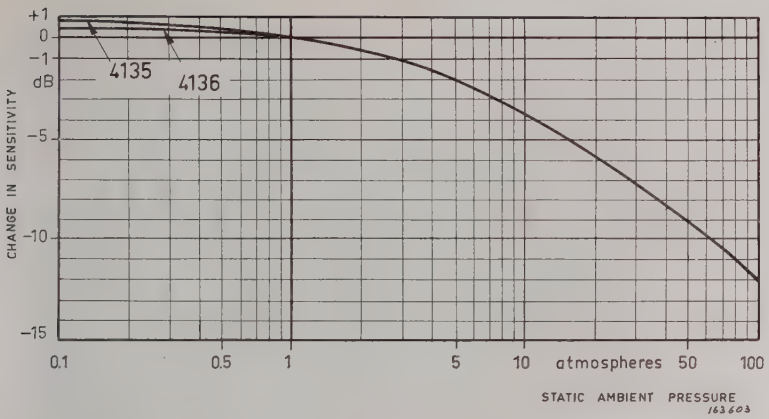


Fig. 2.18. Variation of the quarter-inch microphone sensitivity as a function of the static ambient pressure. Measurements made down to 14 mmHg (0.02 atm., or 26 Km - 86000 ft. altitude) show that the sensitivity in vacuum would be less than 1 dB higher than the sensitivity at 1 atm. (Only valid up to 3000 Hz. See below).

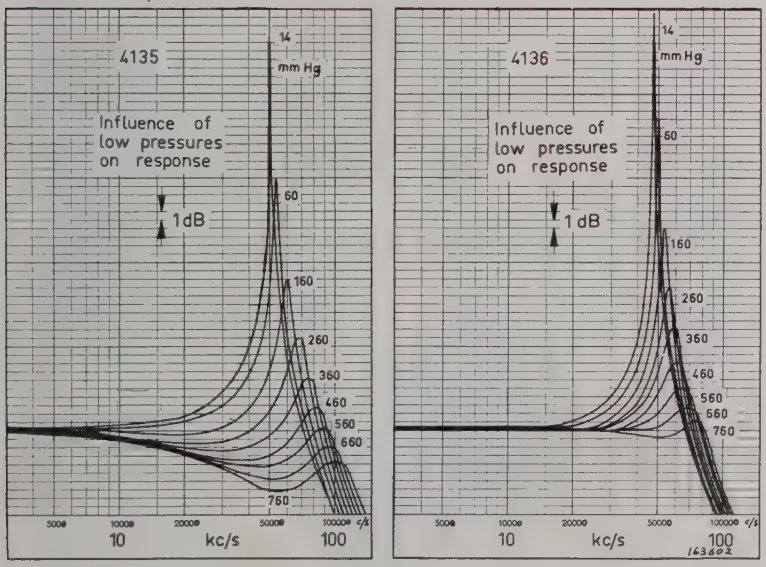


Fig. 2.19. Influence of the static ambient pressure on the frequency response of the quarter-inch microphones.

cartridges. There is then a temporary risk of electrical noise and cracking. When stable ambient conditions are regained, the condensed water will evaporate within less than 15 minutes through the pressure equalization aperture. A complete description of these phenomena will be found in the B & K Technical Review No. 1-1960, p. 12—15. A fully protected microphone system for permanent exposure outdoors is available in the half-inch range, e.g. Type 2615 + 4133 + UA 0056.
In the absence of condensation, the relative humidity percentage has practically no influence on the microphone sensitivity.
N.B. The use of dessicators under storage is not necessary.

12. **Influence of Vibrations.**
The influence of a vibration will depend on the direction in which it is applied to the microphone. When the force is acting in a direction which is parallel to the axis of symmetry (i.e. at right angles to the diaphragm) the sensitivity to vibration is mainly determined by the mass of the diaphragm and of the air column on both sides of it. The microphone will be most sensitive to vibration acting in this direction, but due to the low diaphragm mass, the signal produced from vibrations having an acceleration of 1 G is as low as an equivalent sound pressure level of 88 dB. The sensitivity to vibrations acting at right angles to the axis of symmetry parallel to the diaphragm is much lower.
The influence of vibration on the microphone adaptor and preamplifier may in some cases be much higher due to resonances in the mechanical structure, which in turn excite the grids of the tube. This may be reduced by proper mounting of the cathode follower in a soft rubber pad or by wrapping it in a soft rubber foam sheet (Fig. 4.8). Another solution would be to use one of the flexible adaptors UA 0122 or UA 0123.

13. **Sensitivity to Magnetic Fields.**
The sensitivity to magnetic fields is extremely low. Even with a very intense field of 50 oersted at 50 Hz having the most unfavorable orientation, the induced output does not exceeded 0.1 mV fundamental and 0.3 mV second harmonic (100 Hz).

3. Accessories

Nose Cone UA 0053.

When measurements are taken in locations where the microphone cartridge is subjected to high speed airflows, it may be useful to mount a Nose Cone instead of the normal protecting grid. The diaphragm will then be fully protected against chance hard particles carried by the air stream and a significant reduction of the turbulence noise will be obtained in most cases.
The presence of the Nose Cone will only modify the free-field response above 20 kHz. It is furthermore noticed by comparing the characteristics of Fig. 3.2 with Fig. 2.3 or Fig. 2.9 that the Nose Cone improves the omnidirectivity of the microphone.

Fig. 3.1. The quarter-inch Nose Cone UA 0053.

Flexible Adaptors UA 0122 and UA 0123.

The flexible Adaptors UA 0122 and UA 0123 have been designed for use with the B & K 1/2″ Microphones (4133—4134) as well as the 1/4″ Microphones (4135—4136). They consist basically of a flexible rod and three mechanical

Fig. 3.3. The Flexible Adaptor UA 0122.

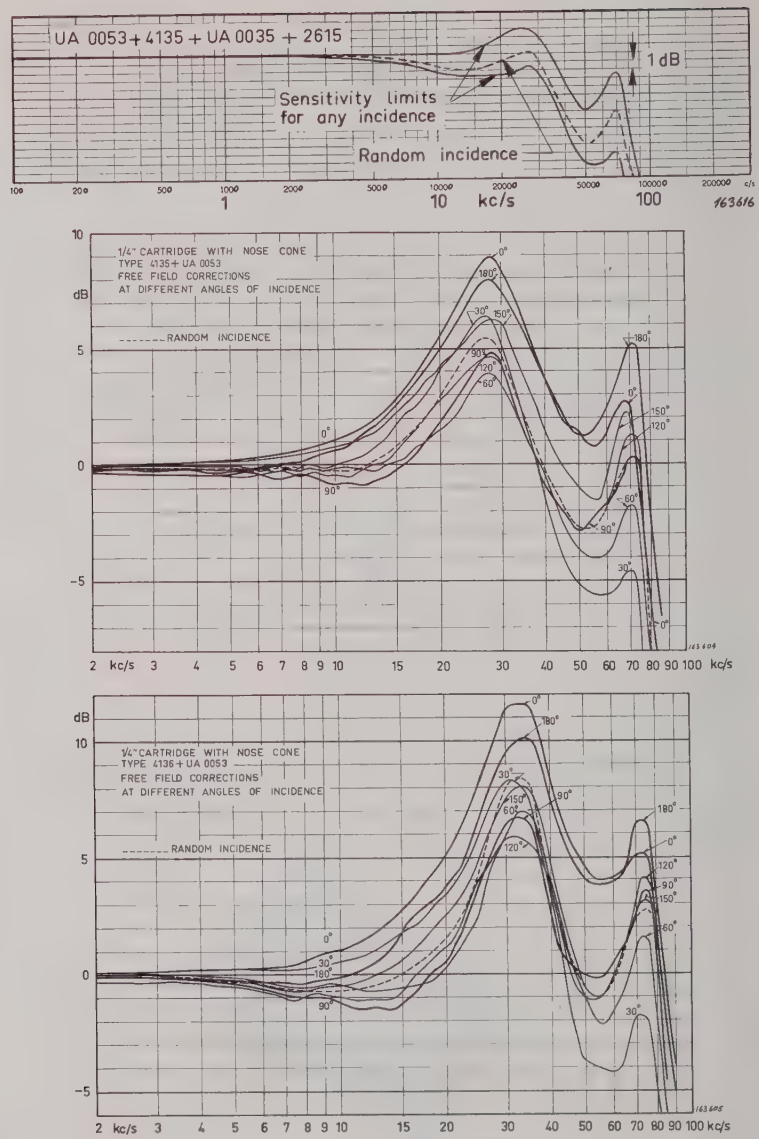


Fig. 3.2. Characteristics of the quarter-inch microphone equipped with Nose Cone.

mounting pieces, see Figs. 3.3 and 3.4. At one end of the rod is placed a mounting arrangement for attachment to a preamplifier Type 2615 (or 2614) and at the other end the Microphone cartridge itself can be mounted. UA 0122 allows side mounting of the cartridge while UA 0123 is designed for end mounting.

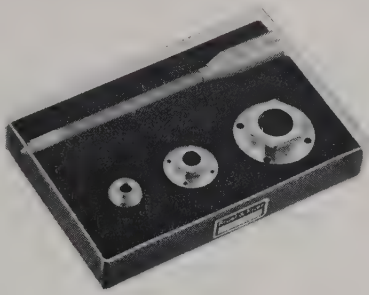


Fig. 3.4. The Flexible Adaptor UA 0123.

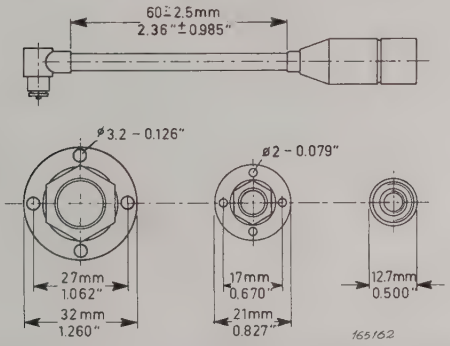


Fig. 3.5. Sketch of the flexible rod and flush mountings contained in UA 0122.

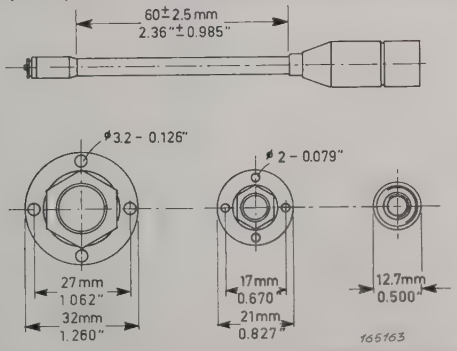


Fig. 3.6. Sketch of the flexible rod and flush mountings contained in UA 0123.

Both Adaptors make use of the well known B & K double screening system which reduces the input capacity, and thus its influence on the microphone characteristics, to a minimum. The increase in input capacitance caused by the Flexible Adaptor is of the order of 2 pF. As insulation materials teflon and silicone treated rubber are used and the inner one of the two screens is of a special mini-noise type.

The 1/4″ Microphones can be mounted directly on the Adaptors while the 1/2″ Microphones require the use of a mechanical conversion arrangement, which is supplied with the Adaptor. Also supplied with the Adaptor are two flush mounting pieces, one for the 1/4″ Microphone and one for the 1/2″ Microphone. The flush mountings are designed with the smallest possible heights.

When the Microphone and Flexible Adaptor are mounted on the Cathode Follower it is recommended to calibrate the complete arrangement by means of a Pistonphone Type 4220 or Calibrator Type 4230 if accurate measurements are to be made.

Microphone Stand UA 0049.

This stand fitting all types of B & K microphones is of invaluable assistance in field measurements. It is a lightweight portable tripod with rigid telescopic legs, similar to those used in photographic work, as shown in Fig. 3.7. The height of the Stand can be adjusted from approximately 50 cm to 140 cm. The Tripod Adaptor UA 0028 (seen on top of UA 0049) may be used separately for adapting the microphones on standard camera tripods with thread ⅜″ W.

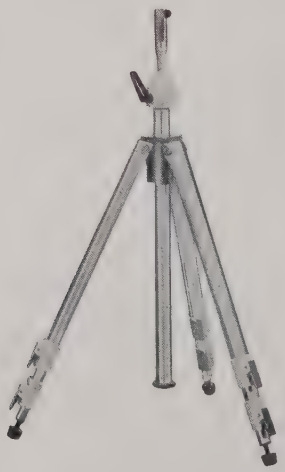


Fig. 3.7. Microphone Stand UA 0049.

Extension Cables.

When it is desired to use the microphones well remote from the associated instruments an extension cable must be used to make the connection. Several standard lengths of extension cables are available for this purpose.
The conductors are polyethylene insulated and the cable is covered with a grey P.V.C. covering.

Extension Cable AO 0027 is a 3 m long multi-core shielded cable supplied with B & K microphone connectors in both ends. The diameter is 6 mm.
The capacity of the signal conductor to ground is approximately 100 pF/m.

Extension Cable AO 0028 is a 10 m long multi-cored shielded cable, supplied with a coaxial signal conductor and B & K microphone connectors at both ends. The diameter is 9 mm. The cable is specially designed to give low microphony, excellent shielding of the signal core and low leakage between the cores enable long runs of cables to be used.
The capacity of the coaxial signal conductor to ground is approximately 57 pF/m (19 pF/foot).

Extension Cable AO 0029, as for AO 0028, but 30 m long.

Tape Microphone Cable AR 0001. This very flexible, flat 7-cored microphone cable is used when sound insulation and reverberation measurements are made in buildings and where it is necessary to carry a microphone cable through closed windows and doors. The flat cable can easily follow sharp bends, the thickness of the cable being 0.2 mm. Cable length: around 30 cm.

Mechanical Adaptor DB 0264.

By screwing the adaptor DB 0264 onto the quarter-inch cartridges, a device having the same external dimensions as the B & K half-inch microphone cartridges Type 4133/34 is obtained. This enables the accessories types UA 0033 (electrostatic actuator, see Appendix) or UA 0040 (see below) etc., which were originally designed for the half-inch microphones, to be used with the quarter-inch microphones.

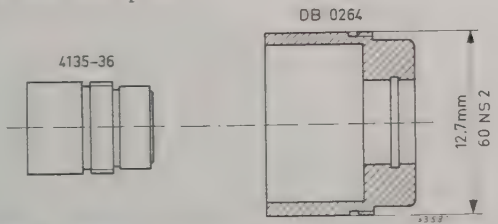


Fig. 3.8. Quarter-inch cartridge and adaptor DB 0264.

Probe Microphone Kit UA 0040.

Probe microphones can be used for a variety of applications such as measurements in the ear, measurements on sound insulating materials and

within intricate machinery, as well as in other inaccessible places, e.g. small ducts, furnaces, oilburners, etc. The Kit includes 4 probe tubes, adaptor and gasket for mounting on the B & K ½″ microphone cartridges, or quarter-inch provided with the above mentioned adaptor DB 0264. The outside diametres of the 4 probes are: o.5, 1, 2, and 4 mm, and the length is 240 mm (except for the o.5 mm diameter probe which is 120 mm long).
In addition, a coupler where the 4 different probe tube diameters can be adapted is supplied together with a small earphone enabling determination of

Fig. 3.9. The Probe Microphne Kit Type UA 0040.

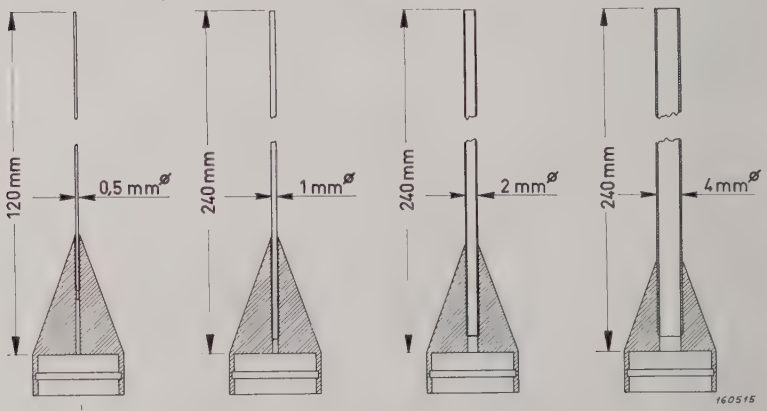


Fig. 3.10. Sectional drawing of the probe tubes.

the frequency response curves of the probe microphone by means of a B & K Beat Frequency Oscillator. The response of the probes may be adjusted as illustrated in Fig. 3.11.
The requirement of length and width of the probes will vary with the applications. The necessary tools and damping material to make them suitable for any particular application are supplied with the Kit. The detailed description and the instructions for use of the UA 0040 are contained in the manual 4133/4134.

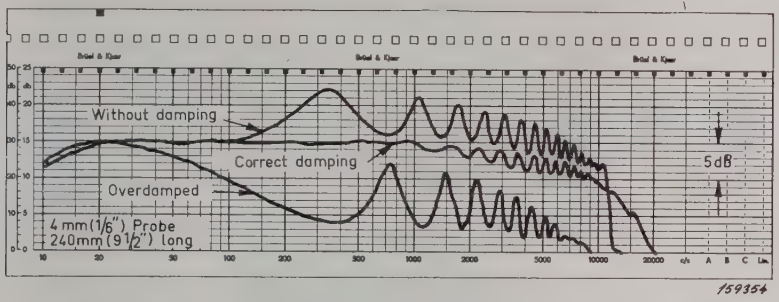


Fig. 3.11. Example of frequency response of a probe microphone with different degrees of damping.

Two-Channel Microphone Selector Type 4408.

This instrument enables the user to make comparisons between the outputs of two B & K condenser microphones by connecting them alternately to a single indicating device. (The B & K microphone amplifiers and analyzers are able to power two cathode followers at a time).
The switching can be done manually by means of a toggle switch on the

Fig. 3.12. Two-Channel Microphone Selector Type 4408.

top of the instrument, or automatically by remote control of the relay. The external switch then replaces the function of the toggle switch. The simultaneous recording of the two signals may thus be driven from the Level Recorder Type 2305 which is provided with a switch operated in synchronism with the paper drive.
Crosstalk is kept to negligible proportions by extra filters in the anode supply circuits to the preamplifiers.

Microphone Power Supply Type 2801.

The Microphone Power Supply is for example used in conjunction with tape recording of measurement data in the field in cases where B & K Amplifiers or Analyzers are not available, or where extremely long extension cables must be used between the microphone and the succeeding amplifier. The power supply unit supplies the necessary filament, anode and polarization voltage for the microphones, and, in addition, it contains a

Fig. 3.13. Microphone Power Supply Type 2801.

transformer stage to convert the output impedance of the cathode follower into an impedance of 50 ohms (voltage ratio 1/6.3) or 200 ohms and 200 ohms symmetrical (voltage ratio 1/3.16).
The power supply unit is heavily stabilized for variations in mains voltage and may be operated from power outlets with 100—115—127—150—220 or 240 volts (50 to 400 Hz).
The Microphone Power Supply can also be employed in conjunction with the above mentioned Microphone Selector Type 4408. For further details the reader is referred to the separate instruction manual for Type 2801.

Appendix

4. Microphone Calibration.

4.1. Error in an Absolute Sound Level Measurement.

Considering the various standard*) errors a, b, c - - - which are expected to occur on each of all the different parts of the measuring arrangement, the total standard error is $S = \sqrt{a^2 + b^2 + c^2 + \text{- - - -}}$

In the case of the measuring arrangement of Fig. 2.2, for example, the different sources of error to be considered in the measurement of the sound pressure level on the microphone diaphragm are as follows (rough estimation):

(a) Microphone cartridge calibration: o.2 dB after proper corrections.
(b) Transmission loss of the cathode follower and loading of the cartridge: o.1 dB.
(c) Polarization voltage's deviation from 200 V: o.2 dB.
(d) Voltage calibration of the 2603: o.1 dB.
(e) Meter scale and attenuators: o.2 dB.
(f) Reading error: o.1 dB.
(g) Uncertainty on the frequency response of the measuring equipment, which should be taken into account when considering bands of noise having frequencies differing greatly from the frequency of microphone calibration (250 Hz). Still considering the equipment of Fig. 1.2, this uncertainty is about ± o.1 dB from 100 Hz to 20 kHz, and ± o.3 dB from 50 Hz to 50 kHz for a free-field measurement at 0° incidence with the 4135 or at 90° incidence with the 4136. When measuring broad band noise through the A-B-C weighting networks of the 2604 the probable frequency response uncertainty is of the order of ± o.3 dB.

Equating o.1 dB to 1.1 %, o.2 dB to 2.2 % and o.3 dB to 3.3 %, the standard error in the measured result will thus be

$S = \sqrt{2.2^2 + 1.1^2 + 2.2^2 + 1.1^2 + 2.2^2 + 1.1^2 + 3.3^2} = 5.4\ \% = \pm$ o.48 dB

and the probability of obtaining larger errors than o.8 dB is less than o.1.

Note: In some cases of irregular statistical distribution of signal amplitudes. errors may be caused by the limited averaging time (damping) of the meter or by the limitation of the RMS rectifier possibilities.

If a better accuracy is desired, the most practical and reliable solution is to make a direct calibration of the whole measuring arrangement before each

*) The standard error s is such that there is 68 % chance of obtaining errors smaller than s, 90 % smaller than 1.65 s and 99 % smaller than 2.58 s.

series of measurement by means of a calibrated sound source. Then the errors (a) (b) (c) (d) outlined above are replaced by the source calibration error and the calibrating reading error. When using a Pistonphone Type 4220, these errors may be estimated each to 0.1 dB. The total standard error is then reduced to S = 0.40 dB (0.27 dB for pure tones, for which error (g) may be eliminated.

4.2. Pistonphone Type 4220.

The Pistonphone Type 4220 (Fig. 4.1) is a small, portable battery-driven unit weighing only 1.5 lbs. which is extremely well-suited for field calibration. The pistonphone produces, when fitted to a B & K microphone, a sound pressure level of 124 dB at 250 Hz which is known with an error of less than ±0.2 dB. This enables a direct calibration in dB SL of a meter scale to be made, and measurements therefore to be taken with an excellent accuracy if the frequency response and the dynamic linearity (including the attenuators) of the instrumentation following the microphone are ascertained. A barometer is supplied with the instrument for direct reading of ambient pressure corrections, together with adaptors for fitting to the different B & K microphones.

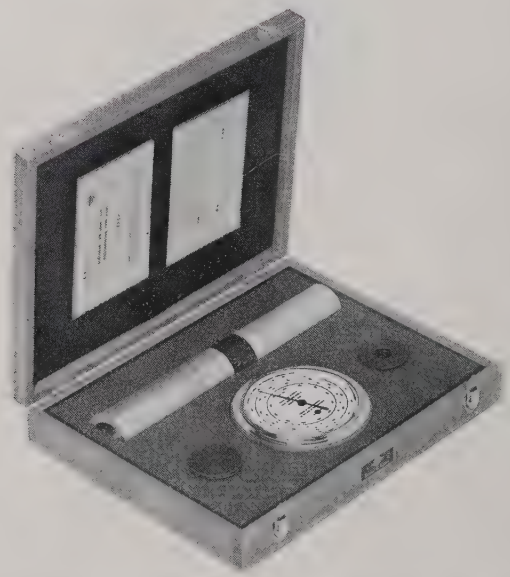


Fig. 4.1. Pistonphone Type 4220 in case with Barometer and Coupling Adaptors for fitting to the different B & K microphones.

4.3. Electrostatic Actuator Type UA 0033.

The diaphragm of a condenser microphone may be influenced by electrostatic attraction in a way which is similar to the action of sound waves. This is done very simply by placing a metallic grid in close proximity to the diaphragm and applying an alternating voltage between them. A test signal of constant amplitude and varying frequency is thereby easy to obtain.

Fig. 4.2. Electrostatic Actuator Type UA 0033.

The grid is shaped in a way which allows free movement of the air situated between grid and diaphragm in order to ensure that only the electrostatic attraction is communicated to the microphone. Since the attraction is proportional to the square of the voltage, the test frequency is doubled. The Electrostatic Actuator Type UA 0033 (Fig. 4.2) is designed for use with the half-inch and quarter-inch condenser microphones. The actuator is placed on the microphone held vertically. It has three glass studs which contact the periphery of the cartridge diaphragm and give an accurate spacing of a few tenths of millimeters between actuator grid and diaphragm. In the case of the quarter-inch cartridges, an adaptor DB 0264 is screwed onto the cartridge with its front "flush" to the cartridge diaphragm.

When using a B.F.O. Type 1013 as voltage source, the maximum available voltage of 120 volts will provide an equivalent sound pressure level in the order of 80 dB which generally is sufficiently above the ambient noise level in laboratories. A higher signal level may be obtained by using the 800 volts DC bias provided by the Microphone Calibration Apparatus Type 4142. This is the method used in production at B & K.

Since the electrostatic "pressure" is not affected by ambient conditions, the actuator is an excellent means for the determination of the variations in microphone sensitivity under changing environments.

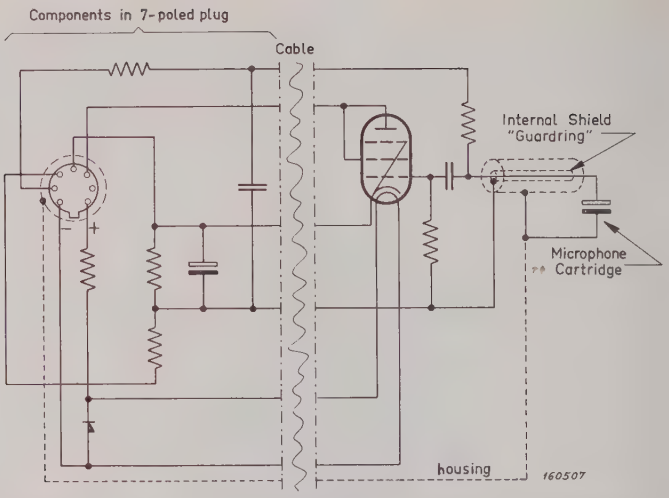


Fig. 4.3. Basic diagram of the cathode-follower showing the principle of the guard ring system.

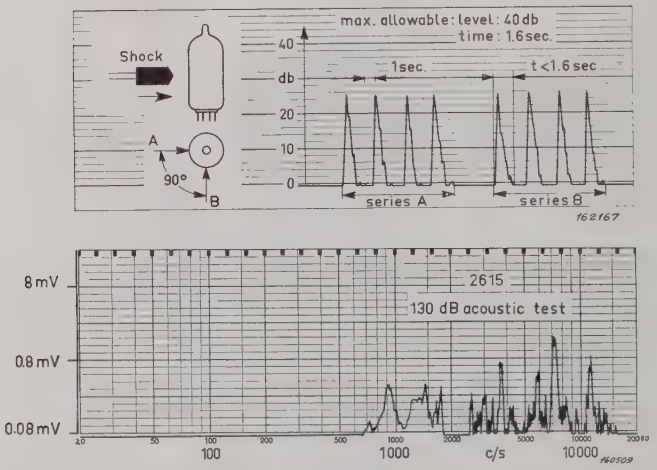


Fig. 4.4.

(a) Test of a tube EF 731. Microphonics are excited by means of two series of lateral shocks and recorded whereby the amplitude and duration of transients are closely checked.

(b) Recording of the output from a ½" cathode follower loaded by a 6 pF dummy cartridge, exposed to a sound field of 130 dB at varying frequency.

Cathode Follower 2615.

The 2615 contains a vacuum tube cathode follower input stage in the microphone end of the housing. A basic diagram of the 2615 is shown in Fig. 4.3.
Hz (Fig. 4.4).
Before mounting each tube is tested for sensitivity to shock according to the Mil-E1C specifications. In addition, during the final test the cathode followers are exposed to a sound pressure of 130 dB where their microphonics is checked to be smaller than 8 mV throughout the frequency range 20—20000 Hz (Fig. 4.4).
The input circuitry is internally screened by means of a "guard ring" which is connected to the cathode of the tube. In this way the input capacity is reduced to an absolute minimum. The guard ring is extended to the top of the cathode follower which allows the use of low capacity extension connectors such as UA 0035 between microphone cartridge and cathode follower.
The capacitive load due to the three signal conductors of the multi-core cable causes through the guard ring circuit the input capacity to increase with frequency. This is shown in Fig. 4.5 together with the consecutive loss of sensitivity of the complete microphone in a typical case. When adjusting the frequency response of the cartridge this loss is taken into account in order to provide a flat frequency response of the complete microphone.
The power supplies necessary to operate the cathode followers are provided

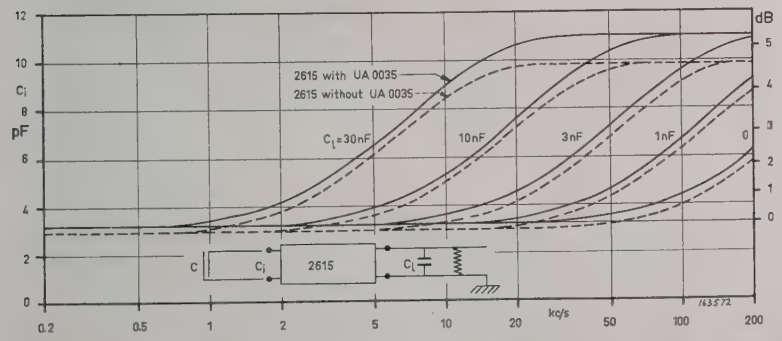


Fig. 4.5. Variation of the equivalent input capacitance C_i of the cathode follower 2615 as a function of frequency for different external capacitive output loads. The corresponding loss in microphone sensitivity is equal to $\frac{C + 3.25}{C + C_i}$, *C being the polarized cartridge capacity given in pF on the individual calibration chart. This loss is given in dB on the right scale in the case where C = 6 pF.*

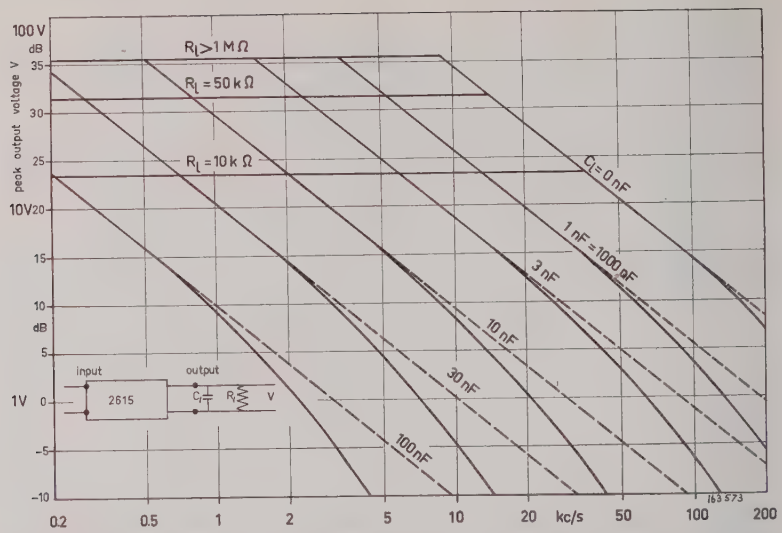


Fig. 4.6. Upper limit of the dynamic range of the cathode follower. The limit given by this graph is the peak output voltage corresponding to a distortion of 4 % as a function of frequency and loading. The dashed lines show the corresponding input voltage (minus 0.9 dB).

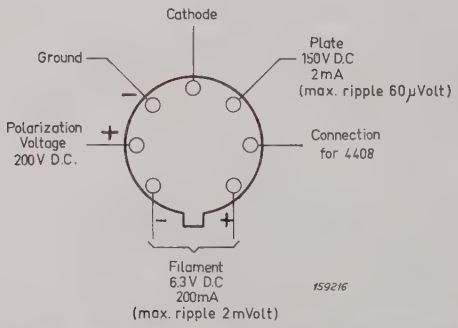


Fig. 4.7. Plug connection of the cathode follower (viewed from outside).

by the B & K measuring amplifiers, or the Microphone Power Supply Type 2801, via the multipin-socket at the front panel as shown in Fig. 4.7.
The cathode followers can be used separately whenever a high input impedance amplifier is needed for voltage measurements at the output of small transducers etc. An input adaptor JJ 2614 is supplied for this purpose with

each cathode follower. This adaptor can be screwed onto the cathode follower housing instead of the UA 0035 and contains a capacitor of a few thousand pF for blocking the 200 V DC polarization voltage. The adaptor provides a standard 14 mm coaxial socket fitting the B & K JP 0018 plug.

14. **Spurious Microphonics.**

The spurious microphonics is determined by replacing the normal microphone cartridge by a dummy cartridge, i.e. a cartridge having a zero sensitivity,

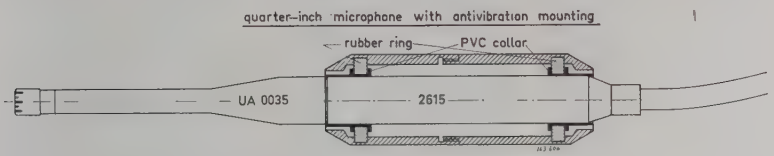


Fig. 4.8. Demonstration fitting used in Fig. 4.9.

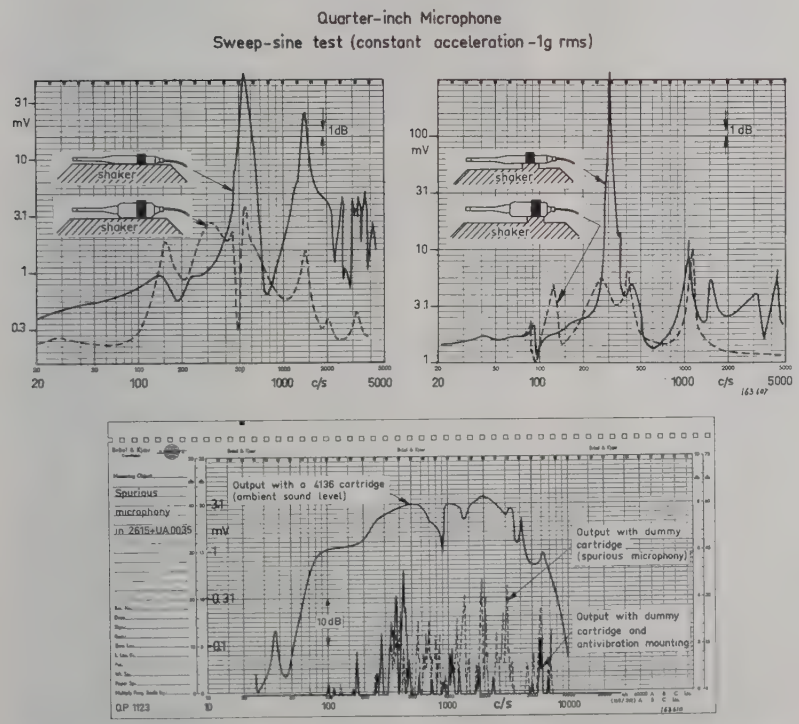


Fig. 4.9. Output from a quarter-inch microphone subjected to a frequency sweep vibration test and microphonics test.

and comparing the output signals. This is illustrated as a function of frequency in Fig. 4.9.
With the exception of a few peaks, the microphonics is always more than 20 dB below the signal. It can be reduced by using a vibration damping muffler such as a sheet of foam nylon wrapped around the cathode follower.

Specifications 2615.

Input Impedance: 700 MΩ in parallel with 3 ± 0.5 pF.
(Below 10 Hz and above 2 Hz: more than 200 MΩ in parallel with 3 ± 0.5 pF).

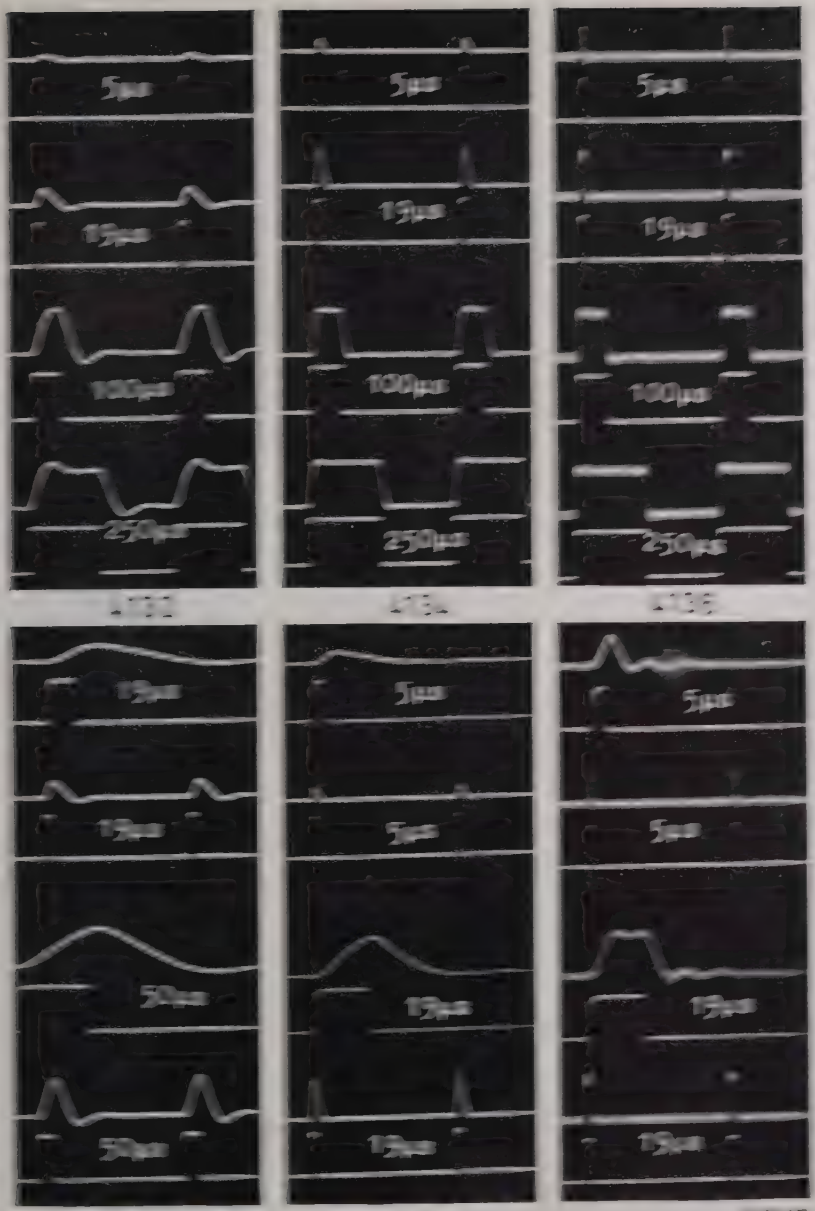
Output Impedance: Approximately 750 Ω.

Transmission Loss: Voltage gain = — 0.9 dB ± 0.2 dB.

Self-generated Noise Level: Approximately 80 μV at cathode follower output, with the input loaded by a capacitor of 8 pF (20 Hz—200 kHz).

Distortion: 4 % distortion occurs with input voltages higher than 20 volts r.m.s. at 1 kHz. (See Fig. 1.10 for higher frequencies).

Tube: 5899 (EF31), specially tested for low microphonics.


5μs
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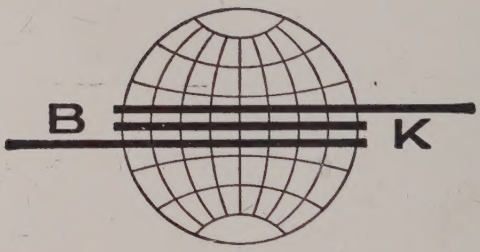
Type	4131 + 2612/13	4132 + 2612/13	4133 + 2614/15	4134 + 2614/15	4135 + UA 0035 + 2618	4136 + UA 0035 + 2618
Nominal Cartridge Diameter	1 inch		1/2 inch		1/4 inch	
Frequency Response*). Flat within ± 3 dB in the range:	**Free-field (0° incidence)** 20 Hz to 18 kHz	**Pressure** 20 Hz to 7 kHz	**Free-field (0° incidence)** 20 Hz to 40 kHz	**Random incidence and Pressure** 20 Hz to 20 kHz	**Free-field (0° incidence)** 5 Hz to 100 kHz	**Random Incidence and Pressure** 5 Hz to 70 kHz
Sensitivity*) at preamplifier output Dimensions of cartridge:	50 mV per N/m^2 — 26 dB re 1 V per N/m^2		10 mV per N/m^2 — 40 dB re 1 V per N/m^2		2.8 mV per N/m^2 —51 dB re 1 V/N/m^2	1.4 mV per N/m^2 —57 dB re 1 V/N/m^2
Cartridge open-circuit sensitivity*)	— 25 dB re 1 V per N/m^2		— 38 dB re 1 V per N/m^2		—50 dB re 1 V/N/m^2	—56 dB re 1 V/N/m^2
Dynamic Range (from equivalent A-weighted noise level to 4 % harmonic distortion)	15—146 dB re 2×10^{-5} N/m^2		32—160 dB re 2×10^{-5} N/m^2		60—174 dB re 2×10^{-5} N/m^2	66—180 dB re 2×10^{-5} N/m^2
Resonant Frequency (90° phase angle)	10 kHz	8 kHz	25 kHz	25 kHz	100 kHz	75 kHz
Polarization Voltage	200 V					
Polarized Cartridge Capacity*)	70 pF	60 pF	20 pF		6.4 pF	
Equivalent Air Volume (at 1 atm.)	0.15 cm^3	0.15 cm^3*)	0.01 cm^3	0.01 cm^3*)	0.0005 cm^3	
Temperature Range: up to	100°C	100°C	with 2614: 150°C (continuous) 250°C (intermittent) with 2615, 2618: 100°C (limited by cable insulator)			
Temperature coefficient between —50°C and +60°C	less than ± 0.01 dB/°C					
Ambient Pressure Coefficient (increase of sensitivity for a 100 mm Hg decrease of pressure around 1 atm.)	0.2 dB		0.1 dB		less than 0.1 dB	
Relative humidity influence	less than 0.1 dB (in the absence of condensation)					
Max. rate of climb at ground level for less than 1 dB change in sensitivity	ar. 500 m/s (1500 ft/s) (up to 9600 m/s on request)		ar. 2000 m/s (6000 ft/s)		ar. 10000 m/s (30000 ft/s)	ar. 20000 m/s (60000 ft/s)

*) Individually calibrated.



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